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EXPERIMENT STATION EXPENDITURES: STATE SHARE AND POPULATION EFFECTS

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There are a growing number of studies that estimate the economic returns to public sector agricultural research. The estimated rates of return from these studies should be an important input into public sector decisionmaking on the allocation of federal and state funds to agricultural research. However, there have been few attempts to develop and fit empirical models that explain resources allocated to agricultural experiment station research. Some work has been done by Peterson (1969), Guttman (1978), and by us in an earlier paper (Huffman and Miranowski).

In our earlier paper, we developed a model of resource allocation for state-produced research by agricultural experiment stations consisting of a demand and supply equation for research, an equation for allocating state government revenues to research, and an expenditure market "equilibrium" equation. A reduced-form expenditure equation was fitted to 144 state observations obtained by pooling cross-sectional data on the 48 states for 1960, 1965, and 1970. The fitted model was quite successful in explaining research expenditures per capita.

In this paper, we extend our earlier analysis. We consider the separate impact of federal (CSRS) funding, population size, and number of farms on agricultural experiment station expenditures. Also, we consider alternative specifications of the dependent variable of the reduced-form expenditure equation. They are total expenditures, and the total expenditures deflated by population, number of farms, and total agricultural output.

Original Model of Resource Allocation to State Experiment Stations

In an earlier paper (Huffman and Miranowski), we estimated a model of resource allocation for state-produced research at agricultural experiment stations consisting of demand and supply equations for applied research, an equation for allocating state revenues to research, and an expenditure "market" equilibrium equation. We assumed that demanders and suppliers of research interact through the state legislature to determine the "equilibrium" size of expenditures on experiment station research.

The quantity demanded of indigenously applied agricultural research was specified to be a function of the size and other characteristics of a state's agricultural output, agricultural input prices, farmers' education, extension, and agricultural research in other states. The characteristics of a state's agricultural output were primary determinants of shifts in the demand for indigenous applied agricultural research. The diversity of agricultural products increased the demand for indigenous applied research, implying the final research products are commodity specific.

Indigenous applied agricultural research was produced and supplied by agricultural experiment stations. The production of research requires, as inputs, the services of administrators, researchers (or scientists), research assistants, and secretaries, as well as scientific publications, office space and equipment, laboratory space and equipment, electronic computers, greenhouse space, experimental plots and farms, and research animals and plants. As a first approximation, we assumed agricultural experiment stations produce research output at minimum cost; directors choose input combinations that minimize the cost of producing a given quantity of research, and they do not change cost-minimizing input combinations because particular inputs yield satisfaction directly to them.

The supply or cost function of indigenously applied agricultural research was specified to be a function of prices of variable inputs, of the quantity of research output, and of factors exogenous to current resource allocation decisions. The last set of variables was chosen to measure the efficiency of research production

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and, hence, the cost of research. They included the mix of the station's researchers, the type of research appointments, the extent of Ph.D. programs, extension contact with researchers, availability of borrowable research, number of final research areas, and the number of research centers.

Demanders of research did not pay suppliers of research in our model, but rather, decisions were made at the state government level on the share of state revenue to be spent on indigenously applied agricultural research. Although the demand and supply functions for research provided an equilibrium "shadow" price and quantity, the model required a behavioral equation for allocating state government revenue (McMahon) to agricultural research (or to nonresearch activities). We took the size of total state governmental revenues (which includes intergovernmental transfers) as predetermined, but we took the share of these revenues allocated to agricultural research as endogenous. Thus, political-economic clout was required to obtain funds for agricultural research. The director of the agricultural experiment station would request research funds based upon his information of research costs and of the demand for research conveyed to him through contact with producer groups, advisory boards, input supply firms, and feedback through extension personnel. Demanders may lobby the state legislator directly or through interest groups to achieve their political influence.

We hypothesized that farm owner-operators, operators of large farms, and farm organizations were the strongest lobbyists for agricultural research. State agricultural research expenditures were positively related to the share of owner-operator and large farms. As a measure of farm organization lobbying, we used multiple membership in farm cooperatives, which was also positively related to research expenditures.

The final equation of the model was the expenditure "market" equilibrium condition; desired agricultural research expenditures must equal state revenue allocated to agricultural research. We assumed that each of the four equations (including an eqilibrium condition) had a $\log_e$ linear form, and we derived a reduced-form expenditure equation and reduced-form coefficients from the three-equation system.

Extension and Respecification of the Model

We propose to extend and respecify the original model of resource allocation for research at state agricultural experiment stations. The model will be extended to include the impacts of federal funding, size of state population, and number of farms. Also, alternative specifications of the dependent variable will be considered, including total research expenditures (undeflated), and the total expenditures deflated by number of farms, agricultural output, and population.

Historically, federal funds appropriated on a formula basis (CSRS funds) have been a primary source of state agricultural experiment station funding. Although state appropriations for research have substantially exceeded federal support in most states in recent years, the federal contribution can be expected to have a significant income effect on total station research expenditures. _A priori_, the direction of the income effect of federal funds on research expenditures is uncertain. We might expect the marginal effect of CSRS funds on total research expenditures to be positive. If federal funds replace state funds, the marginal effect on total research funds of a \$1 increase in federal money would be less than \$1.

The size of the state's population is a scale variable. Increasing a state's population, holding all other variables expressed in per-capita units constant, will increase the number of both direct and indirect beneficiaries of agricultural research expenditures, as well as the revenue base for state appropriations.

In this paper, we hypothesize that the number of farms enters both the research demand, supply, and allocation equations. Holding agricultural output constant, the general public might prefer that a larger, as opposed to smaller, number of farms should benefit from research. This would parallel Orr's argument for the public-good nature of AFDC income transfers. On the supply side, the marginal cost of distribution of research output to additional farms is positive, but is small relative to the marginal cost of knowledge production. The net effect of number of farms on research expenditures is uncertain.

Station research expenditures were deflated by population in the original model. Guttman (1978) used per-capita units in his empirical analysis. The per-capita specification also has the advantage of a more homoscedastic error term than a total expenditures specification. Others (_e.g._, Orr) have used number of recipients as the deflator. In addition to per-capita units, we consider three alternative specifications of the dependent variable: (1) total expenditures, (2) expenditures per unit of agricultural output, and (3) expenditures per farm. When using per-farm units, the appropriate exogenous variables are also deflated by the number of farms. Intuitively, a particular specification of the model may seem more appropriate, but the algebraic differences are not overly significant, and the empirical results should be similar.

The Empirical Analysis

The data base, the empirical specification of the variables, and the regression results from fitting the reduced-form of the state expenditure equation for experiment station research are presented and discussed in this section.

The Data Base and the Variables

The basic data source on expenditures and other characteristics of the agricultural experiment stations is the USDA publication, Funds for Research of State Agricultural Experiment Stations and Other State Institutions. States in the conterminous United States are the units of observation, and expenditures for the fiscal years of 1960, 1965, and 1970 are used as the dependent variable. The cross sections are combined to provide a more rigorous test of the model.

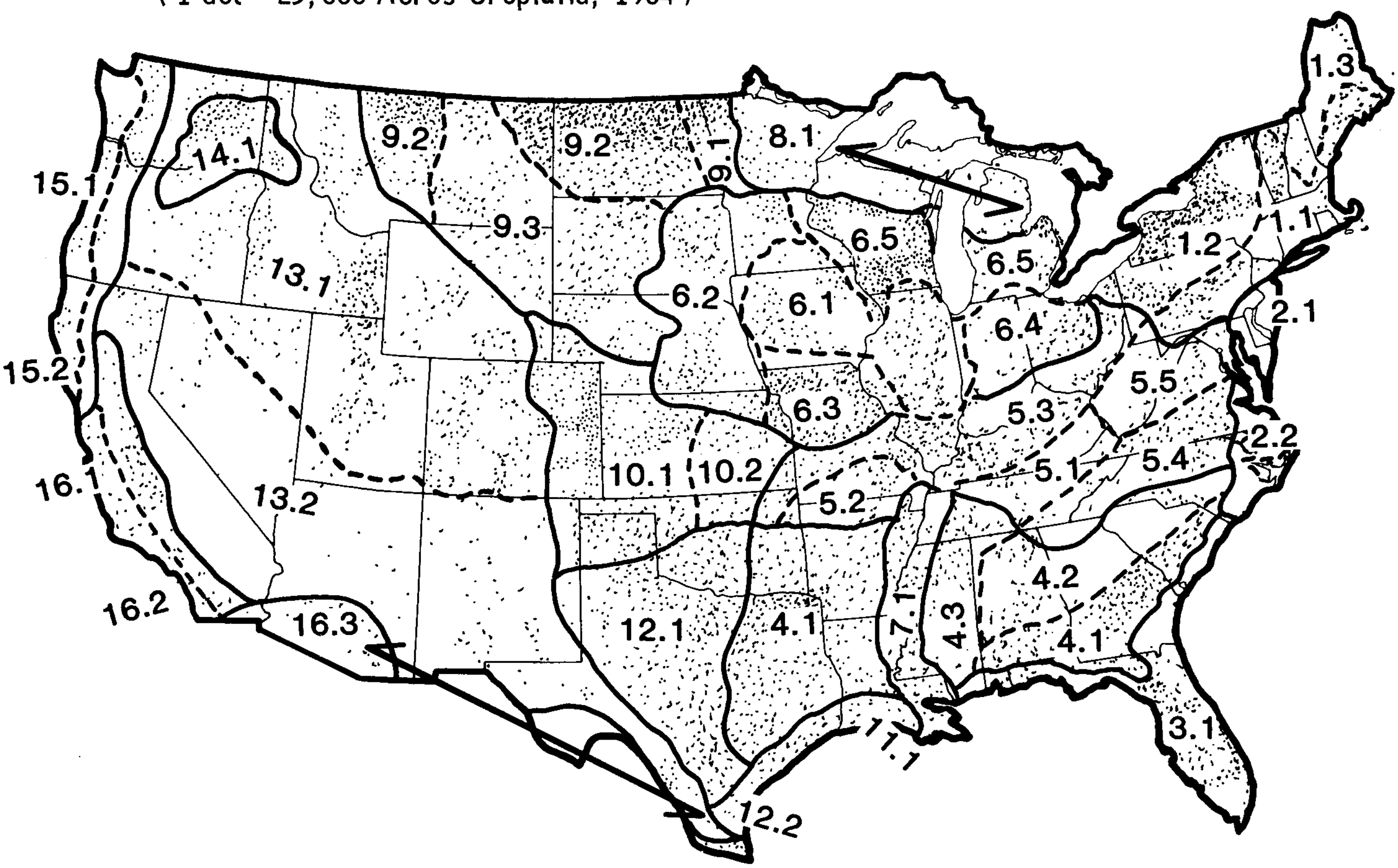
Most of the variables are constructed on a state per-capita or per-farm basis by dividing them by the size of the state's population (U.S. Dept. of Commerce, 1961, 1966, and 1971) or by the state's number of farms (U.S. Dept. of Commerce, 1962, 1968, and 1973), respectively. Our original model used state population as the deflator of the appropriate variables. This analysis compares the original specification of the dependent variable with agricultural research expenditures deflated by number of farms, by agricultural output, and undeflated. The alternative deflators do have implications for the public/private-good nature of agricultural research knowledge.

The dependent variable is a state's grand total obligation of funds for the fiscal year by the experiment station (and other state institutions) less nonfederal funds available from fees, sales and miscellaneous sources, then divided by the size of its population or by its number of farms. Agricultural output is measured as net annual sales (total value of farm products sold, less purchases of livestock and poultry and of noncommercial feeds for livestock and poultry), (U.S. Dept. of Commerce, 1962, 1968, and 1973) per capita or per farm, lagged one year. An index of concentration (diversity) of a state's agricultural output is constructed as the summation of the squared production share of each of 18 different agricultural commodities or commodity groups. The index is largest if a state's agricultural output consists of only one commodity or commodity group (it is one), and is smallest if a state produces an equal value of each of 18 different commodity groups (18/324). For input prices, we use only a state's annual average hourly wage rate for hired labor, without board and room, lagged one year (USDA, 1961, 1965, and 1970). The education level of farm operators is a Welch-weighted (Welch, 1966, 1970) average number of years of schooling completed by farm operators (U.S. Dept. of Commerce, 1962, 1968, and 1973). Extension is the grand total of a state's expenditures on extension per capita or per farm, lagged one year.

We constructed two measures of research activity outside a given state from data made available to us by Robert Evenson and described in Evenson (1978). The relevant set of states to consider in constructing these variables was determined by the boundaries of geoclimatic regions and subregions derived from the 1957 Yearbook of Agriculture (see Figure 1). These areas have relative homogeneity of soils and climatic factors. The subregional applied research stock (competitive research) is the summation of past commodity-specific livestock and crop research expenditures, and applied agricultural engineering and farm management research expenditures aggregated over states with similar agricultural subregions outside the state. Applied research expenditures were assumed to have a 30-year useful life, and linear weights were applied to aggregates over time with seven years of increasing, eight years of constant, and 15 years of declining weights (Evenson, 1978). Basic research is applicable over a wider geoclimatic area. The regional basic research stock (borrowable research) is the summation of past basic research expenditures for states in similar geoclimatic regions outside the state. Basic research was assumed to have a 40-year useful life, and linear weights were applied to aggregates over time with seven years of increasing, eight years of constant, and 25 years of declining weights. Outside applied and basic research are in per-capita or per-farm units.

Four characteristics associated with agricultural experiment stations follow. A research center's variable is derived as the number of research stations and substations (USDA, Professional Workers in State Agricultural Experiment Stations), including main campus, per 10,000 farms. The average share of budgeted time for research is the number of full-time equivalent station researchers, divided by the total number of station researchers engaged full- or part-time in research (USDA, Funds for Research). A variable measuring the size of the university's Ph.D. degree programs is derived. This variable is defined as the annual average (two-years) number of Ph.D. degrees earned in other areas (excluding agriculture and forestry) at universities associated with agricultural experiment stations (U.S. Dept. HEW, Earned Degrees Conferred) relative to the size of the state's population. The Ph.D. degree variable measures the potential for intrauniversity borrowing of knowledge by station researchers.

Figure 1. U. S. Agricultural Geoclimate Regions and Subregions.
(1 dot - 25,000 Acres Cropland, 1964)



1. Northeast Dairy Region
2. Middle Atlantic Coastal Plain
3. Florida and Coastal Flatwoods
4. Southern Uplands
5. East-Central Uplands
6. Midland Feed Region
7. Mississippi Delta
8. Northern Lake States
9. Northern Great Plains
10. Winter Wheat and Grazing Region
11. Coastal Prairies
12. Southern Plains
13. Grazing -- Irrigated Region
14. Pacific Northwest Wheat Region
15. North Pacific Valleys
16. Dry Western Mild-Winter Region

The state budget constraint is total revenue per capita of the state government from all sources, including intergovernmental transfers (U.S. Dept. Comm., *Statistical Abstracts*). The impact of federal funding on a state's agricultural experiment station research expenditures (*i.e.*, the substitutability between state and federal appropriations for SAES research) is measured by CSRS funds (USDA, *Funds for Research*) per capita or per farm. Farm size distribution is measured as the share of large farms (sales ≥ $40,000) and the share of medium-sized farms (sales $2,500-39,999). The proportion of owner-operators is a weighted average number of full owners and of part owners. Full owners are given an arbitrary weight of 1, and part owners a weight of 0.5. The only accessible farm organization membership data are for cooperatives. The cooperative membership variable is the total estimated number of memberships in marketing, farm supply, and related service cooperatives. Average share of budgeted time for research is the number of full-time equivalent station researchers, divided by the total number of station researchers engaged full- or part-time in research (USDA, *Funds for Research*). Two variables measuring Ph.D.-to-research faculty ratio is the (three-year centered) average number of Ph.D. degrees earned in agriculture and forestry from departments associated with the agricultural experiment station (U.S. Dept. HEW, *Earned Degrees Conferred*), divided by the number of full-time equivalent station researchers. The Ph.D. degrees in other areas is the annual average (two-years) number of Ph.D. degrees earned in other areas (excluding agriculture and forestry) at universities associated with agricultural experiment stations (U.S. Dept. HEW, *Earned Degrees Conferred*) relative to the size of the state's population.

The state budget constraint is total revenue per capita of the state government from all sources, including intergovernmental transfers (U.S. Dept. Comm., *Statistical Abstracts*). The impact of federal funding on a state's agricultural experiment station research expenditures (*i.e.*, the substitutability between state and federal appropriations for SAES research) is measured by CSRS funds (USDA, *Funds for Research*) per capita or per farm. Farm size distribution is measured as the share of large farms (sales ≥ $40,000) and the share of medium-sized farms (sales $2,500-39,999). The proportion of owner-operators is a weighted average number of full owners and of part owners. Full owners are given an arbitrary weight of 1, and part owners a weight of 0.5. The only accessible farm organization membership data are for cooperatives. The cooperative membership variable is the total estimated number of memberships in marketing, farm supply, and related service cooperatives (USDA, *Statistics of Farmer Cooperatives*) per capita or per farm.

Empirical Results

The results from fitting reduced-form expenditure equations by the method of least-squares to the 144 pooled observations are reported in Tables 2 and 3. These results include the alternative specifications of the dependent variables, as well as the model extensions including state population, number of farms, and federal funding. The hypothesized positive relationship between the size of agricultural output and expenditures on agricultural research is consistent. The negative coefficient, when expenditures are deflated by output, is not inconsistent. Algebraically, the coefficient of ln(AGOUT) in the ln(RY) equation should be equal to the coefficient, minus one of ln(AGOUT) in the ln(R) equation. All four specifications support the hypothesis of commodity specificity of research final products although the CONC coefficient is not statistically significant in the total expenditure model. The interaction terms are reasonably consistent across models.

The signs on LAR and MED are not consistent with the hypothesized relationship in the total expenditure, extended per-capita and per-farm models, but these coefficients are not significantly different from zero. The same result is obtained for the share of owner operators in the total expenditure specification.

The ln(WAG) and ln(ED) coefficients are consistent across models and significantly different from zero at the 5% level. Increasing farm wage rates induce research expenditures to develop labor-augmenting technologies. Also, the sign of the education coefficient in the original model, which was puzzling, consistently has a negative impact on the demand for station research.

The research borrowing variables continue to perform well in the alternative specifications. The negative relationship between ln(ARES) and total expenditures is puzzling but statistically insignificant. Conceivably, states with large total expenditures on station research (*e.g.*, California, New York, Florida) are sufficiently isolated from similar geoclimatic regions where competitive applied research may occur.

The allocation equation variables, ln(REV) and ln(COOP), produce results consistent with those of the original model. Likewise, the coefficients of the variables for supply characteristics of station research are consistent.

The variables of particular interest in this analysis are ln(FED), ln(POP) and ln(FARM), which extend the original model. The impact of CSRS funds per capita on total state research expenditure per capita is negative, if we hold constant the population and number of farms. Otherwise, the impact on total research expenditures of ln(FED)

Table 1. Summary Statistics for Expenditures on U.S. State Agricultural Experiment Station Research,

Variables	Symbol	Unit	Mean	Standard Deviation
Expenditures on Experiment Station Research Per Capita	R	$0.1 per person	14.0	9.3
Net Agricultural Output Per Capita	AGOUT	$s of output per 1,000 people	2,359.0	2,174.3
Index of Commodity Concentration of Agricultural Output	CONC	--	0.21	0.08
Proportion Large Farms	LAR	--	0.07	0.06
Proportion Medium-Sized Farms	MED	--	0.53	0.15
Proportion Owner-Operators	OWN	--	0.73	0.09
Wage Rate of Hired Farm Labor	WAGE	$ per hour	1.20	0.31
Index of Farmers Education	ED		1.49	0.28
Extension Expenditures Per Capita	EXT	$ per person	1.39	0.81
Research Centers Per Farm	CEN	Centers per 10,000 farms	3.06	4.06
Subregional Applied Research Stock Per Capita	ARES		16.12	19.80
Regional Basic Research Stock Per Capita	BRES		3.92	5.47
Budgeted Share of Research Time	SR	--	0.70	0.12
Ph.D. Degrees Earned in Agriculture and Forestry Per Full-Time Equivalent Researcher	APHD	Ph.D. degrees per researcher	0.07	0.08
Ph.D. Degrees Earned Outside Agriculture and Forestry Per Capita	OPHD	Ph.D. degrees per 1,000 people	0.03	0.03
State Revenue Per Capita	REV	$1,000 per capita	0.984	1.02
Co-op Membership Per Capita	COOP	Member/1,000 people	57.42	73.14
Total Expenditures on Exp. Station Research	TR	$100	38,289.8	34,922.2
Exp. on Experiment Station Research Per Unit Net Agricultural Output	Ry	$ per $ output	.0089	.0076
Expenditures on Exp. Station Research Per Farm	RF	$100 per farm	1.28	1.77
Federal (CSRS) Exp. on State Experiment Station Research Per Capita	FED	$0.1 per person	4.28	3.10

Table 1. (Continued)

Variables	Symbol	Unit	Mean	Standard Deviation
Number of Farms	FARM	Number	66,524.3	53,740.4
State Population	POP	1000's persons	3,983.4	4,107.1
Net Agri. Output Per Farm	AGOUTF	$100 output per farm	128.49	109.24
Extension Exp. Per Farm	EXTF	$1000 per farm	.09	.08
Subregional Applied Research Stock Per Farm	ARESF		2.14	6.82
Ph.D. Degrees Earned Outside Agriculture and Forestry Per Farm	OPHDF	Ph.D. degrees per farm	.004	.006
Co-op Membership Per Farm	COOPF	Members/farm	2.29	1.85
Federal (CSRS) Expenditures on State Experiment Station Research Per Farm	FEDF	$100 per farm	.39	.72

Table 2. OLS Estimates of Reduced-Form Models for Expenditures on State Agricultural Station Research Deflated by Output, Farms, and Population, 1960, 1965, and 1970.

Variable	(1) ln(RY)	(2) ln(RY)	(3) ln(TR)	(4) ln(TR)	(5) ln(R)	(6) ln(R)
Constant	-1.30 (-1.99)[a/]	2.46 (2.12)	8.13 (11.86)	2.40 (2.06)	-1.12 (-1.72)	2.40 (2.06)
ln(AGOUT)	-.67 (-7.81)	-.46 (-3.76)	.53 (5.91)	.51 (4.15)	.31 (3.64)	.51 (4.15)
CONC	3.47 (1.64)	5.40 (2.67)	6.78 (3.06)	5.47 (2.68)	5.47 (1.74)	3.67 (2.68)
LAR	2.06 (2.29)	-.26 (-.22)	-.86 (-.92)	-.07 (-.06)	2.08 (2.33)	-.07 (-.06)
MED	.53 (1.93)	.03 (.11)	-.30 (-1.07)	-.03 (-.09)	.43 (1.60)	-.03 (-.09)
OWN	.86 (2.61)	.39 (1.19)	-.02 (-.06)	.28 (.86)	.72 (2.26)	.28 (.86)
ln(WAG)	.55 (2.11)	.70 (2.86)	.92 (3.35)	.68 (2.76)	.54 (2.07)	.68 (2.76)
ln(ED)	-.54 (-2.34)	-.79 (-3.56)	-1.08 (-4.49)	-.71 (-3.15)	-.47 (-2.05)	-.71 (-3.15)
ln(EXT)	.33 (3.26)	.35 (3.65)	.33 (3.12)	.37 (3.78)	.35 (3.45)	.37 (3.78)
ln(CEN)	.22 (5.61)	.13 (2.95)	.05 (3.12)	.11 (2.47)	.20 (4.95)	.11 (2.47)

Table 2. (Continued)

Variable	(1) ln(RY)	(2) ln(RY)	(3) ln(TR)	(4) ln(TR)	(5) ln(R)	(6) ln(R)
ln(ARES)	.11 (3.32)	.04 (1.16)	-.02 (-.51)	.03 (.98)	.10 (3.01)	.03 (.98)
ln(BRES)	-.02 (-1.90)	-.04 (-3.20)	-.06 (-4.62)	-.04 (-3.16)	-.03 (-1.96)	-.04 (-3.16)
ln(SR)	.38 (3.08)	.39 (3.33)	.44 (3.39)	.40 (3.40)	.39 (3.18)	.40 (3.40)
ln(OPHD)	.05 (2.74)	.05 (2.98)	.05 (2.61)	.05 (3.05)	.05 (2.84)	.05 (3.05)
ln(REV)	.07 (1.03)	.08 (1.24)	.14 (1.83)	.15 (2.22)	.14 (1.98)	.15 (2.22)
ln(COOP)	.06 (1.93)	.07 (2.41)	.07 (2.15)	.07 (2.40)	.06 (1.97)	.07 (2.40)
(CONC) x ln(AGOUT)	-.51 (-1.93)	-.79 (-3.07)	-.97 (-3.49)	-.79 (-3.07)	-.53 (-2.02)	-.79 (-3.07)
(LAR) x ln(ARES)	-.67 (-2.51)	-.34 (-1.34)	-.05 (-.18)	-.33 (-1.28)	-.63 (-2.39)	-.33 (-1.28)
ln(FED)	.15 (1.79)	-.32 (-2.12)	-1.02 (-11.50)	-.27 (-1.75)	.18 (2.08)	-.27 (-1.75)
D70[b]	.37 (2.20)	.56 (3.46)	.86 (4.82)	.67 (4.11)	.50 (2.94)	.67 (4.11)
D60	.13 (.70)	-.06 (-.35)	-.29 (-1.55)	.11 (.60)	.29 (1.63)	.11 (.60)
ln(FARM)		-.14 (-1.26)		-.13 (-1.15)		-.13 (-1.15)
ln(POP)		-.29 (-1.75)		.73 (4.38)		-.27 (-1.64)
R^2	.92	.93	-.94	.95	.92	.93

[a] Values in parenthesis are t-statistics.

[b] D70 and D60 are dummy variables for 1970 and 1960, respectively.

Table 3. OLS Estimates of Reduced Form Model for Expenditures on State Agricultural Station Research Deflated by Number of Farms, 1960, 1965, and 1970.

Variable	(1) ln(RF)	(2) ln(RF)
Constant	-1.83 (-2.89)	2.82 (2.60)
ln(AGOUTF)	.72 (5.54)	.66 (5.57)
CONC	2.64 (1.98)	3.51 (2.92)
LAR	-1.82 (-1.89)	-1.56 (-1.78)
MED	-.06 (-.21)	-.14 (-.51)
OWN	.64 (1.87)	.33 (1.05)
ln(WAG)	.61 (2.39)	.77 (3.31)
ln(ED)	-.55 (2.42)	-.87 (-4.00)
ln(EXTF)	.41 (4.22)	.27 (2.86)
ln(CEN)	.11 (2.46)	.10 (2.43)
ln(BRES)	-.04 (-3.89)	-.04 (-4.21)
ln(SR)	.29 (2.36)	.37 (3.24)
ln(OPHD)	.05 (2.82)	.05 (2.99)
ln(REV)	.03 (.51)	.10 (1.50)
ln(COOPF)	.05 (1.46)	.04 (1.46)
(CONC) x ln(AGOUTF)	-.74 (-2.82)	-.89 (-3.74)
D70	.26 (1.57)	.50 (3.22)
D60	.17 (.92)	-.04 (-.21)
ln(FEDF)	.41 (5.40)	-.26 (-1.79)

Table 3. (Continued)

Variable	(1) ln(RF)	(2) ln(RF)
ln(POP)		.24 (4.76)
ln(FARM)		-.70 (-5.74)
R2	.96	.97

is positive. Holding ln(POP) and ln(FARM) fixed, the implication is that an increase in federal funding per capita or per farm will decrease total state research expenditures. Likewise, the current concern over real reductions in Hatch funding may result in an increase in total experiment station research expenditures, other things equal. To say the least, the implications are somewhat surprising, especially since we are holding other factors fixed, and since these results are consistent across equations.

States with more farms tend to spend less per capita and per unit of agricultural output on experiment station research, but the coefficient on ln(FARM) is not significantly different from zero at a standard level of confidence. The number of farms, which means more potential recipients of research knowledge (i.e., public good), has a negative impact, even when holding the size distribution of farms constant. Economies may exist in supplying public research knowledge to a larger number of recipients, other things equal, producing the negative coefficient on ln(FARM). Population does have a positive impact on the total research expenditures per capita and per farm equations. Larger states spend more total dollars on agricultural research, more per farm, and more per capita.

The statistical significance of some (e.g., LAR, MED, OWN, ln(REV)) of the original explanatory variables is reduced by the inclusion of ln(FED), ln(POP), and ln(FARM) in the model, but generally, the signs are consistent.

In the per-farm equation, increasing the share of large farms reduces per-farm expenditures on agricultural research. It may indicate that larger farmers acquire privately supplied research knowledge, or that public support for research per farm is less as the share of large farms rises.

Implications and Summary

All of our model specifications are really very similar, so one should not be surprised by the similarity and consistency of the results. In most cases, the explanatory variables perform quite well. However, some specifications of the model (i.e., deflators) may have a stronger intuitive acceptance than others. An analysis of the residuals of the different specifications might provide some guidance in choosing between them.

Increasing (decreasing) CSRS funds for state experiment station research, holding population and number of farms constant, not only substitutes for other funds, but results in a decrease (increase) in total research expenditure. Although the result is surprising, among other things, it may indicate that formula funds, which do not divert significant scientific effort from research to grant-seeking, are more efficient at the margin in producing a given level of research output.1/

States with larger populations spend more on station research than their smaller counterparts; the relationship between ln(TR) and ln(POP) is positive. Yet, the negative relationship between population and per-capita research expenditures, holding other per-capita variables and number of farms constant, tends to support the hypothesis that agricultural research is a public good, whose consumption is nonrival (i.e., there are economies of size in the provision of public research knowledge, other things equal).

In supplying research knowledge to farmers, additional support for the public-good hypothesis is provided by the coefficient of ln(AGOUT) which is positive, but less than unity. Increasing agricultural output by 10% increases research expenditures, but only by 3 to 6%, indicates economies in spreading research output over more units of output.

The number of farms has a negative impact on research expenditures when holding population and agricultural output constant. Even though more farms imply more potential recipients of benefits of applied research and possibly greater numbers to influence state appropriations, the negative coefficient may reflect a less efficient farm sector. Also, larger numbers may create organizational problems that hamper effective lobbying efforts.